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Comparative Analysis of Diesel with Fuel Extracted from Waste Plastics

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Abstract
Plastics have oven their way into our daily lives and pose a tremendous threat to the environment. Over a 100 million tonnes of plastic are produced annually worldwide, and the used products have become a common feature at overflowing bins and landfills. Though work has been done to make futuristic biodegradable plastics, there have not been many conclusive steps towards cleaning up the existing problem. Here, the process of converting waste plastic into value added fuels is explained as a viable solution for recycling of plastics. Thus two universal problems such as problems of waste plastic and problems of fuel shortage are being tackled simultaneously. The waste plastics are subjected to depolymerisation, pyrolysis, thermal cracking and distillation to obtain different value added fuels such as petrol, kerosene, and diesel, lube oil etc. Converting waste plastics into fuel hold great promise for both the environmental and economic scenarios. Thus, the process of converting plastics to fuel has now turned the problems into an opportunity to make wealth from waste
Keywords— **Waste plastic, Pyrolysis, Fractional distillation, properties, diesel.**

I. INTRODUCTION

Just about 280 million tons of plastic are produced every year by humans and a large amount of that plastic ends up in the surroundings, harming aquatic life and other ecosystems. Because of the chemical bonds which makes plastic so sturdy, makes it similarly resistant to natural processes of dilapidation. Given that plastics are non-biodegradable in character, it is very complicated to eliminate the waste plastics from nature.

The bulk of the plastic waste ends up in landfills, and becomes a carbon sink where it may take up to 1000 years to decay and potentially seep out pollutants into the soil and water. The uninhibited incineration of plastic produces polychlorinated dibenzo - pdioxins, a carcinogen.

In this regard, by converting the throw away plastic into crude oil will have two benefits. First of all, the harm caused due to plastic waste can be eliminated to a great extent and secondly, some amount of oil can be extracted by the same by following some processes, which can be further purified to be used as a fuel in wide application areas such as domestic fuel, fuel for automobiles and industries etc. Thereby, our reliance on fossil fuels will lessen to a certain extent [1].

In the year 2004, a nationwide survey was conducted where according to the survey, approximately 10000 tonnes of plastic wastes are generated each day in our country, and out of which only 60% of it was recycled and the remaining 40% was not possible to dispose off. So gradually the plastic that was not possible to dispose of goes on accumulating, there by leading to grim disposal problem. In India, plastics use grew exponentially in the 1990s. During the previous decade, the total consumption of plastics was twice as fast (12% p.a). The present growth rate in Indian polymer consumption (16% p. a) is clearly higher than that in China (10% p. a) and many other key Asian countries [2].

Owing to the fossil fuel disaster in the past decade, mankind has to focus on developing other source of alternate energy such as biomass, hydropower, geothermal energy, wind energy, solar energy, and nuclear energy. Developing of alternative-fuel technologies is being investigated so that it can be a replacement for fossil fuels. The focused technologies are bio-ethanol, biodiesel lipid derived biofuels, waste oil recycling, pyrolysis, gasification, dimethyl ether, and biogas [3].

Converting waste plastics into useable fuel is looks like a promising answer since they are energy rich. This conversion process seems achieved by conventional refinery processes such as pyrolysis, gasification, hydrocracking, catalytic cracking and others. Among the above conversion process, the most promising technologies are the pyrolysis process. Pyrolysis is a thermal degradation process that occurs in the absence of oxygen. Waste plastics can be broken down through the pyrolysis process into three products; liquid, gas and solid (small amount) [4].

At the present time, significant research has been focused on diesel engines because of the great drivability and the high efficiency over a large load range. In spite of the fact that diesel engines generate a major amount of NO_X and PM emissions, they are experiencing rapid growth. As a consequence, the search for substitute fuels to replace the petroleum diesel is considered necessary [6].

II. METHODOLOGY

In this experimental work, three main processes like depolymerisation, pyrolysis and fractional distillation have been followed in order to obtain pure plastic pyrolysis oil (PPO). Initially a waste plastic is turned out into a crude oil by pyrolysis process and latter impure crude oil from pyrolysis process is distilled at different temperature ranges by fractional distillation process.

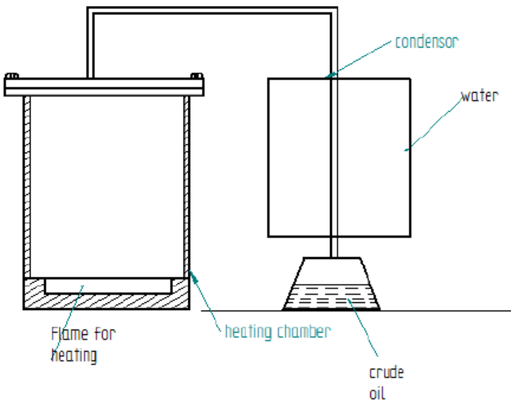

Figure 1: Line diagram of pyrolysis setup

Depolymerisation process includes pyrolysis process as shown in figure 1, where polymers are converted into monomer by heating. Pyrolysis is a thermo-chemical decomposition of organic material at elevated temperatures in absence of oxygen. The reactor temperature is set to 300°C - 350°C, plastic present inside the rector chamber undergoes pyrolysis, i.e. breakdown of macromolecules (polymer) into smaller molecules (monomer).Once the set temperature is reached, the reaction time of 2hr is set from that point on. During the thermal cracking process plastic portions are not broken down immediately because plastics have short chain hydrocarbon to long chain hydrocarbon. First stage of heat applied breaks down only the short chain hydrocarbon. When temperature is increased the plastic carbon-carbon bond breakdown slowly. As the temperature is still increased the long chains breakdown step by step. During this thermal cracking process some light gas such as methane, ethane, propane and butane are produced.

The produced gases are condensed in a condenser into crude oil. Once the crude oil is collected completely, the reactor lid is opened when the temperature of reactor is below 50 °C so as to remove the remaining solid residue, i.e. plastic tar as shown in figure 4.

III.FRACTIONAL DISTILLATION PROCESS

In this process, the chemical mixture is separated into its chemical fractions at their respective boiling points and then condensed into liquid. The setup for fractional distillation process is as shown in figure 2.

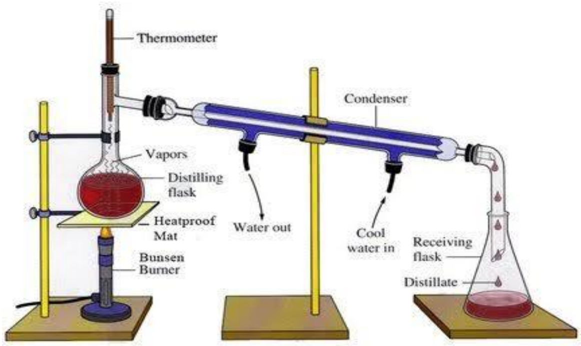

Figure 2: Fractional distillation setup

The crude oil extracted from plastic during pyrolysis as shown in figure 3, is distilled in fractional distillation setup. Before distillation the round bottom flask is cleaned and dried in such a way that no moisture is present in the flask. Then about 100ml of crude oil is filled in the round bottom flask and heated .For collecting the distillation sample1, the lower and upper temperature are set to 100°C and 170°C.Once the liquid stops dripping into the collection vessel the setup is removed to carry out the same cycle for distillation sample2. Sample2 lower and upper temperatures are set at 170°C and 220°C respectively. Also the same procedure is followed for distillation sample3 of lower and upper temperature of 220°C and 290°C respectively as shown in figure 5.

Figure 3: Crude oil extracted during Pyrolysis process

Figure 4: Plastic waste tar after Pyrolysis process

Figure 5: Samples from fractional distillation process

IV. TESTS

After samples of liquids were obtained at different temperatures by fractional distillation, to assess the various properties these distilled liquids, various test were carried out. The process and results of these tests are as follows:

Density is one of the important properties of any oil. To find viscosity of the oil sample we should know the value of the density. Density is the ratio of mass to the volume. Apparatus used to measure the density is 50cc flask and electronic weighing machine. 50cc flasks used to measure the 50cc of the oil which gives volume of the oil and mass of oil is measured using electronic weighing machine.

The viscosity of sample1, sample2 and sample 3 were checked using Ostwald viscometer. 15ml of the sample were taken in a viscometer setup and checked for the time taken for the flow of the liquid from A to B mark in viscometer and then the results obtained were compared with water to get the viscosity value. The viscosity value thus obtained in Ostwald viscometer is dynamic viscosity and to convert dynamic viscosity to kinematic viscosity divide dynamic viscosity by density of sample.

The calorific value of all 3 samples which were obtained from the fractional distillation process, the calorific value was obtained using bomb calorimeter. 1gm of each sample is weighed and tested in bomb calorimeter, and its calorific value calculated.

Flash and fire point of the sample1, sample2 and sample3 were calculated using Cleveland Open Cup setup. Initially sample is filled in the cup up to the given mark. Then heated slowly and to check the flash and fire point flame is brought near the cup for every 2 degree rise of temperature. The corresponding flash and fire points are noted down.

The results of the above following tests are tabulated in the given table.

Table 1.Comparison between Properties of Diesel and experimental fuel samples derived from plastic

Liquid Sample	Density in gm/cm^3	Kinematic Viscosity in cst	Calorific value in MJ/kg	Flash point in °C	Fire point in °C
Sample 1	0.7376	0.7640	44.5714	6	13
Sample 2	0.7665	1.3949	43.7052	53	61
Sample 3	0.7826	2.6180	42.9352	91	103
Diesel	0.8320	1.9 – 4.1	44.8	Vary between 52 and 96	-

V. RESULTS AND DISCUSSION

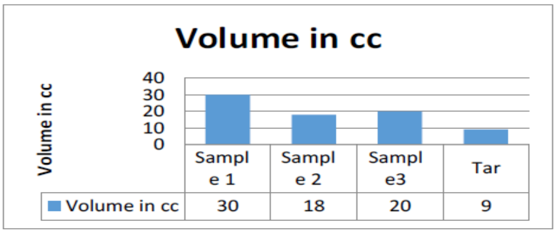

Figure 6: Volume in cc v/s Sample

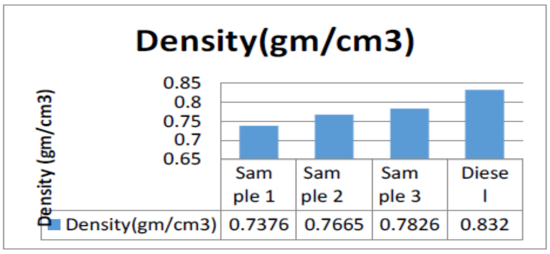

Figure 7: Density v/s Liquid sample

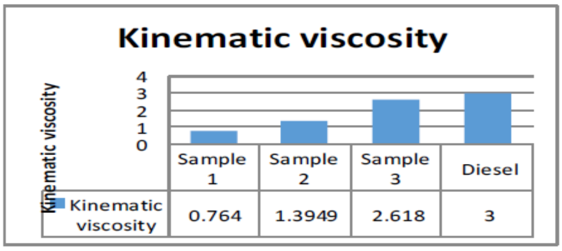

Figure 8: Kinematic viscosity v/s Liquid sample

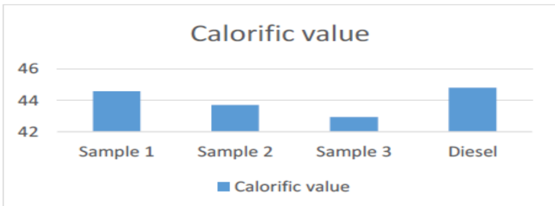

Figure 9: Calorific value v/s Liquid sample

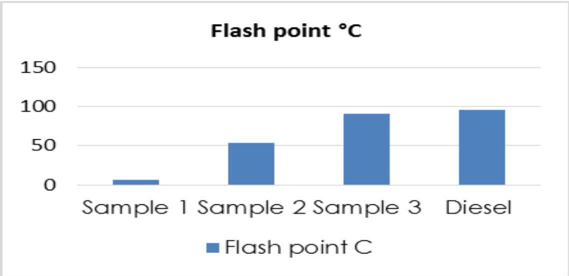

Figure 10: Flash point v/s Liquid samples

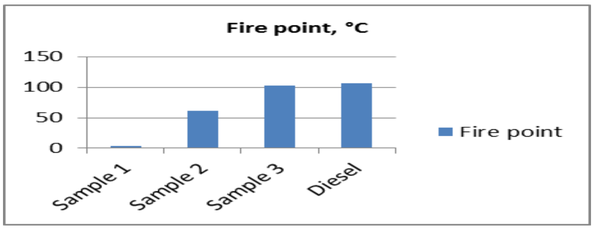

Figure 11: Fire point v/s Liquid samples

The results from the graph can be interpreted as follows:

In this work, 3 fuel samples at three different temperature ranges from, 100ml of crude oil was extracted by fractional distillation process. From Sample1(100°C - 170°C) 30ml was collected, Sample 2(170°C - 220°C) 18ml of fuel was collected, and from Sample 3(220°C - 290°C) 20ml was obtained .Tar waste of 9ml was also collected from the crude oil. All these are represented in figure 6.

From figure 7, it can be easily concluded that among samples, sample1is having a density of 0.7376 gm/cm^3, sample 2 – 0.7665$gm/cm^3$and sample 3 – 0.7826gm/cm^3. Sample 3 density is nearer to that of diesel density – 0.8320 gm/cm^3. The greater the fuel density, the greater the mass of fuel that can be stored in a given tank and the greater the mass of fuel than can be pumped for a given pump.

From figure 8, among the samples, the kinematic viscosity of sample1 is 0.764cst, sample2 is 1.3949cst, and that of sample3 is 2.618cst. Viscosity of sample 3 is very nearer to the density of diesel (3cst), which indicates that the flow ability for sample 3 will be trouble free.

From figure 9, among samples, sample 1is having a calorific value of 44.57MJ/Kg , sample 2 43.70MJ/ Kg ,and sample 3 42.93MJ/Kg .Calorific value of sample3 is choosen as best by taking calorific value of diesel into consideration. Even though calorific value of sample1 and sample2 is better than sample3 but by considering the various properties of diesel, sample3 properties match approximately with that of diesel.

From figure 10, sample1 flash point is 6°C, sample2 is 53°C, and sample3 is 91°C. Flash point of sample3 is between the diesel flash point ranges (52°C - 96°C). So sample3 is considered as best sample among other samples. From figure 11, regarding the fire point, sample1 fire point is 13°C, sample2 is 61°C and that for sample3 is 103°C. The value of sample 3 agrees with that of diesels fire point 62-106°C. As both flash and fire point are within the range of diesel fuel, storing of fuel of sample 3 will not pose much of a problem. From the above data obtained in this experimental work, it can be concluded that sample3 gives better result when compared with the ASTM D975 petro diesel fuel standard, as to that of sample1 and sample2.

VI. CONCLUSION

Plastics present a major threat to today's society and environment. In this regard, the extraction of liquid fuel by Pyrolysis process studied here presents an efficient, clean and very effective means of removing the debris that has been created by humans over the last several decades. By converting plastics to fuel, the above problem can be addressed to a large extent. By taking into account the financial benefits of the project, it would be a great boon to our economy if improvisation can be done to implement the project on a large scale. So, from the experimental work done it can be concluded that the properties of sample3 fuel are very similar to that of diesel and further studies on this field can yield better results and surely provide a strong platform for us to build on a sustainable, clean and green future.

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